10. Communication requirements

The use of a Manufacturing Information Systems (MIS) interface for robot controllers allows MIS software applications and robot controllers to transfer files and exchange data. The MIS systems will be external to the robot system. At this time, only file transfer capability must be supported.

The robot supplier shall communicate with the GM designated MIS system supplier so the MIS system can accept all required data and file types from the robot.

Note: In the future, GM RS-1 will be updated to require data exchange functionality between the robot controller and MIS application(s).

The robot controller MIS interface for file transfer has a three-fold intent: disaster recovery, change monitoring and plant-wide software distribution.

10.1. Purpose

10.1.1. Disaster recovery

The MIS interface serves as a disaster recovery method. The robot controller shall recover from the disasters including any failure that results in the loss of system and application data files, program logic, or data contained in the robot controller memory.

a. The robot controller shall utilize a TCP/IP/Ethernet based network interface to re-initialize and reload memory.

b. The interface shall facilitate the boot-up of the robot controller and retrieval of software and data into robot memory from a host over an Ethernet network.

c. Upon reloading, the robot controller shall require acknowledgment of the download before allowing motion in any mode.

10.1.2. Change monitoring

The robot controller shall make the currently executing program and data files available for upload and comparison by a UDC application.

The UDC (Upload, Download, Compare) application performs program uploads from and downloads to manufacturing device. It identifies changes to programs by comparing the current robot program logic running in volatile memory with a master copy retained by the UDC application performing the comparison.

10.1.3. Plantwide software distribution

Upon downloading software updates, the robot controller shall require acknowledgment of the download before allowing motion in any mode.

The MIS interface serves as a means for plantwide distribution of software updates. New versions of operating system software, application software, and robot function files will be distributed over a plantwide network to multiple robot controllers connected via the MIS interface. The software update will be

distributed to either one robot controller at a time or to multiple robot controllers simultaneously.

10.2. Network Associations

The robot controller shall support a minimum of 16 concurrent associations (connections).

Future requirements shall increase this value because of an anticipated increase in number of associations (connections). The vendor should be able to change the size of the ARP cache via the boot process. See Address Resolution Services section.

10.3. Network Services

a. The MIS interface shall be compatible with these network services: file transfer and address resolution.

b. Network services shall not adversely impact the performance of the robot at any time.

c. A logical device name instead of an IP address shall be used to reference the robot controller.

10.3.1.File Transfer Service

For disaster recovery, change monitoring and plantwide software distribution, the robot controller shall provide a network interface capable of handling file transfers to and from software application(s) over a plant-wide network. The robot controller's network interface shall facilitate bi-directional file transfers with respect to the robot controller:

- an upload to the application and
- a download from the application.

10.3.1.1. Robot Data File Categories

At times it will be necessary to upload/download only robot data files related to a specific functional area of the robot controller. For this purpose, robot data files related to a functional area are categorized into groups as described in Table 7.

Table 7

Robot Data File Group	Description
Operating System	Files related to the robot operating system.
Supplier Application Files	Application files, pertinent to the manufacturing process, which are provided by the supplier and are common to a number of robots.
User Application Files	Application files, pertinent to the manufacturing process, which are customized by the user and are common to a number of robots.
Robot Path Files	Files related to specific robot functions such as robot path and variable data customizable by the user.
Robot Specific Data Files	Robot specific files containing calibration and configuration data, I/O mapping.
Error Log	Robot system error log files.
Superset	All files from all robot data file groups with the exception of error log files in the case of downloads.

The following list indicates requirements regarding robot data file categories:

a. The supplier shall coordinate with GM to:
   - categorize each of their specific files into the appropriate robot data file group; and
   - determine the specific conditions required to upload/download robot data file groups.

b. The robot controller shall enable the user to upload/download all files within:
   - the operating system group;
   - the supplier application file group;
   - the user application file group; and
   - the robot path file group.

c. The robot controller shall enable the user to upload:
   - all files within the error log group; and
   - all groups of data files as one superset group.

d. The robot controller shall enable the user to download all groups of data files, except system error log files, as one superset group.

e. The user application file group shall be uploaded/downloaded in an ASCII format organized for manual (human) interpretation.

f. The robot path file group shall be uploaded/downloaded in an ASCII format organized for manual (human) interpretation.

g. The error log group shall be uploaded in an ASCII format organized for manual (human) interpretation.

h. In addition to transferring files by group, the robot controller shall enable the user to upload/download each file individually.

10.3.1.2. Upload request

a. Initiation

Requests for robot uploads shall be initiated in the following ways:

1. manually by the user at the robot controller,
2. from a UDC application, and
3. by a device explicitly given read-access.

Table 8 summarizes initiation methods and devices for uploads.

Upload requests initiated manually by the user will occur upon demand during production and non-production times. Automatic upload requests initiated by the UDC application will occur on a periodic, scheduled basis during both production and non-production times.

b. Processing

1. Uploads initiated by any sources that are external to the robot controller shall not be permitted unless the source has been explicitly given read-access to the robot controller.
2. After processing an upload request, the robot controller shall display a status message, indicating:
   - the outcome of upload processing (by code),
   - the outcome of upload processing (by text message reporting),
   - the name of the uploaded file, and
   - the date (month, day and year) and time (hours, minutes, seconds) set on the robot controller.
3. The upload request shall be executed in manual modes as well as during automatic operation.

10.3.1.3. Download request

a. Initiation

1. Downloads initiated by any sources that are external to the robot controller shall not be permitted unless the source has been explicitly given write-access to the robot controller.
2. The robot shall accept only locally initiated Robot Path File and Robot Specific Data File downloads.

Table 8 summarizes initiation methods and devices for downloads.

Download requests will be initiated manually by the user from the robot controller user interface or at a remote plant floor terminal accessing the UDC application. Download requests will occur upon demand during production and non-production times.

b. Processing

1. If the robot controller receives a download request initiated by an external source which has not been explicitly given write-access to the robot controller, it shall reject the response to the request.
2. The rejection response shall indicate a negative completion in the command-reply sequence.
3. The rejection response shall indicate that no access was permitted for the download to the robot controller file system.
4. All responses shall be coded to adhere to the specification for File Transfer Protocol (FTP) replies.
5. If a request to download a single or multiple existing file is initiated at the robot controller, the robot controller user interface shall prompt for verification to overwrite the file.
6. When prompting for verification to overwrite each file in a set of multiple existing files, the robot controller user interface shall provide the user with a choice to:
   - overwrite the file and continue to prompt for the next file to be overwritten;
   - skip the overwrite of the file and continue to prompt for the next file to be overwritten,
   - cancel any further prompting and allow all remaining files to be overwritten; or
   - cancel the download of the remaining files in the set which have not been overwritten.

While an overwrite may not be detected upon issuing a command for file transfer, the file overwrite may be detected in one of many ways. One method is to transfer a file to a temporary file. Upon completing the file transfer, use a system call to determine if the file with the same name already exists. If so, prompt the user for overwrite prior to renaming the temporary file to the name of the existing file. If not, rename the temporary file with the name of the existing file.

7. The downloaded file shall not become active or effect the running process until it is explicitly accepted at the robot user interface.
8. After processing a download request, the robot controller shall display a status message, indicating:

- the outcome of download processing (by code);
- the outcome of download processing (by text message reporting);
- the name of the downloaded file; and
- the date and time set on the robot controller.

9. If a download is unsuccessful, the robot controller shall leave intact all files, which existed immediately prior to the download.

10. The robot controller shall leave intact all files, which existed immediately prior to the download except for the file(s) being downloaded.

At the time of writing, the FTP specification lists code 550 as the reply to a command when the file system permits no access.

Table 8

Upload Request	Download Request	Initiation Method	Initiation Device
Yes	Yes	manually by user	robot controller
Yes	Yes	manually by user	UDC application host
Yes	No	scheduled	UDC application host
Yes	N/A	manually by user	other device explicitly given read-access
Yes	N/A	scheduled	other device explicitly given read-access
N/A	Yes	manually by user	other device explicitly given write-access
N/A	No	scheduled	other device explicitly given write-access

10.3.1.4.File Transfer Performance

File transfers to and from the robot controller shall be performed reliably and to completion and meet the following performance criteria:

a. Completely recover from an aborted file transfer. Recovery shall include at least cleanup of unused data in memory, deletion of temporary files and releasing resources no longer required.

b. Continue communication operations with the network after an aborted file transfer.

c. Utilize the full amount of bandwidth available on the network identified in this specification.

10.3.1.5. Upload and Download Verification

For each robot controller model and configuration, the supplier shall demonstrate and report actual upload and download times for each of the six robot data file groups.

10.3.1.6. File Transfer Service Implementation

For the application of file exchange, the application layer shall be implemented using file transfer protocol (FTP). Refer to RFC 959 for the official specification of the FTP.

a. FTP shall be the protocol used for both directions of program file exchange.

b. The robot controller shall act as both an FTP server and client for file transfer exchange.

10.3.2. Address Resolution Services

The robot controller startup procedure shall include a bootstrap process that shall implement the following address resolution services: DNS, DHCP and Default Gateway.

The robot controller shall use accepted industry communication protocol standards for dynamic address assignment and for acquiring system startup, boot up and configuration information over the network.

10.3.2.1. Domain Name Services (DNS)

The robot controller shall support Domain Name Service (DNS) client operations. Refer to RFC 822 for the official specification of DNS.

10.3.2.2. Dynamic Host Configuration Protocol (DHCP)

The robot controller shall support Dynamic Host Configuration Protocol (DHCP). The robot controller shall use DHCP to acquire its network address. Refer to RFC 1533, 1534, 1541, and 1542 for the official specification of the DHCP protocol.

10.3.2.3. Default Gateway

Address resolution shall be one of the functions of the robot controller startup process.

The use of the “default gateway” parameter value that points to the robot controller takes advantage of features that exist in the MIS fiber optics design deployed across GM facilities. It is suggested that this feature shall be utilized when robot controllers are installed in those manufacturing facilities.

The robot controller shall:

a. Use the address resolution protocol (ARP) to resolve MAC addresses.

b. Use the “default gateway” parameter to point to a MIS network router IP address or the IP address of the robot controller itself.

c. Use DNS and/or DHCP client services to obtain either the MIS network router IP address or the IP address of the robot controller itself.

d. Set the “default gateway” parameter value at boot time upon power up. Verify “default gateway” parameter value when a warm boot occurs. This means the “in memory” value is compared with the value obtained from DNS

and/or DHCP client services. If the compare fails, reset the "default gateway" parameter value. Also, re-register the robot controller if DNS client services are available and if DNS has not automatically registered the new address before responding to the initial "default gateway" parameter query. If the compare is successful, no additional action is required for setting the "default gateway" parameter.

When the "default gateway" parameter value contains the IP address of a MIS network router, the router performs address resolution function.

When the "default gateway" parameter value contains the IP address of this robot controller, the MAC address returned by the ARP shall be cached into the robot controller ARP cache. The ARP cache shall contain Internet Protocol (IP) and physical address pair mappings derived by DNS and/or DHCP client services. The ARP cache shall support the number of associations specified in the Network association section. The ARP cache shall be searched first to resolve the MAC address before issuing an ARP request when the cache is not empty. When the ARP cache is empty or when a search of the cache does not resolve the MAC address or when the ARP cache is full, an ARP request shall be issued.

10.3.3. Network Management Service

To manage the health and status of robot controller communications, the robot controller shall support Simple Network Management Protocol (SNMP). A Management Information Base (MIB) shall be included as part of network management service implementation. Both MIB levels I and II shall be supported. (Refer to MIB I as established by Internet standard RFC 1156, and MIB II as established by Internet standard RFC 1213).

10.4. Network Protocol Implementation

The network protocol implementation shall include the following:

a. The complete communication protocol stack and default robot configuration parameters shall be resident in the robot controller.

b. The protocol stack shall be automatically activated upon robot controller power up.

c. The robot controller shall require no external devices in order to load any software or perform any other service to maintain communications under normal (non-disaster) operating circumstances.

d. Common, open protocols shall be used to implement the protocol stack for the network interface.

e. The protocol stack shall follow the seven-layer Open Systems Interconnection (OSI) reference model as indicated in Table 9.

f. If the robot controller uses one of the operating systems listed in Table 10, then the application and data transport protocols shall be implemented using

the corresponding commercial, off-the-shelf (COTS) product for that operating system.

g. The robot controller shall not reference or make use of hard-coded IP addresses.

Table 9

Open Systems Interconnection (OSI) Reference Model Layers	**Protocols**
Application	File Transfer Protocol (FTP) Dynamic Host Configuration Protocol (DHCP) Domain Name Services (DNS) Simple Network Management Protocol (SNMP)
Presentation	*no implementation*
Session	*no implementation*
Transport	Transmission Control Protocol (TCP)
Network	Internet Protocol (IP) Address Resolution Protocol (ARP)
Data Link	ANSI/IEEE Standard 802.3
Physical	Category 5 Unshielded Twisted Pair (UTP) 10BaseT with RJ-45 connectors at each end. Ethernet shall be connected directly to the board, not via a transceiver or converter board.

Table 10

Acceptable Commercial, Off-The-Shelf (COTS) Products For Implementation of Protocol Stack		
Operating System	**Product**	**Supplier**
Windows NT, Windows95	TCP/IP DNS	Microsoft Microsoft
Windows95	Chameleon	NetManage

10.4.1. Application Protocols

The robot controller shall support file transfer, messaging, dynamic address assignment and network management protocols as specified in Table 9.

10.4.2. Data Transport Protocols

The robot controller shall transport data using the following protocols:

a. Both the presentation and session layers shall be excluded from the network protocol stack; neither one shall be implemented as a null layer.

b. The transport layer, which is used for transporting data from one end system to another end system, shall be implemented using TCP. Refer to RFC 793 for the official specification of the TCP.

c. The network layer, which is used for switching and routing network packets, shall be implemented using the IP. Refer to RFC 791 for the official specification of the IP.

d. The data link layer, which is used for point-to-point frame relaying, shall be implemented using the ANSI/IEEE Standard 802.3.

A null layer implementation provides interfaces to the upper and lower neighboring layers without performing any functionality of that layer. In effect, it only passes data from one interface to another.

10.4.3. Connection

For connection requirements refer to Section 4.18. Internal Ethernet wiring, if required, shall use Category 5 Unshielded Twisted Pair (UTP).